International Friends and Enemies

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“Friends and enemies”: a matrix representation of exposure to global shocks

- Rapid economic growth in China and other emerging countries has seen a drastic change in relative economic size of nations
  - Classic question in international trade is the effect of such economic growth on income and welfare in trade partners
  - Related question in political economy is whether such changes in relative economic size heighten political tension (Thucydides Trap)

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  - Develop bilateral "friends" and "enemies" measures of countries' income and welfare exposure to foreign productivity shocks
  - Sufficient statistics that can be computed using only observed trade database

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  - Develop bilateral "friends" and "enemies" measures of countries' income and welfare exposure to foreign productivity shocks
  - Sufficient statistics that can be computed using only observed trade database
  - Reveal economic mechanisms underlying quantitative results
  - Exact for small shocks in the class of international trade models characterized by a constant trade elasticity
  - For large shocks, we characterize the quality of approximation in terms of observed trade matrices and show in practice almost exact
  - Computationally fast ($>$ 1 million counterfactuals in seconds)
  - Easy to examine sensitivity of quantitative results across alternative models (e.g. many sectors, input-output linkages, economic geography)

“Friends and enemies”: a matrix representation of exposure to global shocks

- First-order effect of a productivity shock in a given country on welfare in each country depends on three matrices of observed trade shares
  - Expenditure shares (**S**): expenditure share of importer on exporter
  - Income share (**T**): share of exporter income derived from each importer
  - Cross-substitution matrix (**M**): how $\uparrow$ competitiveness of one country $\implies$ consumers substitute away all other countries in each market

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- Use this matrix representation to reveal economic mechanisms
  - Income exposure: market-size and substitution effect
  - Welfare exposure: income exposure and cost-of-living effect
  - Partial and general equilibrium effects
  - Evaluate contribution of individual sectors
  - Evaluate contribution of importer, exporter, and third markets

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- Empirical application using NBER world trade data and international relations
  - Impact of productivity shocks on global income and welfare
  - Almost exact approximation to exact hat algebra even for productivity shocks orders-of-magnitude larger than implied by the observed data ($R^2 > 0.999$)
  - As countries become greater economic friends, they also become greater political friends, as measured by UN Voting and strategic rivalries

Related Literature

- Research on sufficient statistics for welfare in international trade
  - Arkolakis, Costinot & Rodriguez-Clare (2012), Adão, Costinot & Donaldson (2017), Adão, Arkolakis and Esposito (2019), Baqaee & Farhi (2019), Galle, Rodriguez-Clare & Yi (2019), Huo, Levchenko & Pandalai-Nayar (2019), Barthelme, Lan & Levchenko (2019), Adão, Arkolakis & Ganapati (2020)
- Theoretical work on the incidence of trade and productivity shocks
  - Hicks (1953), Johnson (1955), Bhagwati (1958)
- Empirical evidence on trade and productivity shocks including China
  - Topolova (2010), Kovak (2013), Autor, Dorn & Hanson (2013, 2014), Hsieh & Ossa (2016), Dix-Carneiro & Kovak (2017), Amiti, Dai, Feenstra & Romalis (2019), Pierce & Schott (2019), Borusyak & Jaravel (2019), Sager & Jaravel (2019).
- Quantitative evidence on trade and productivity shocks
  - Eaton and Kortum (2002), Costinot, Donaldson & Komunjer (2012), Caliendo & Parro (2015), Hsieh & Ossa (2016), Caliendo, Parro, Rossi-Hansberg & Sarte (2018), Monte, Redding & Rossi-Hansberg (2018), Dvorkin, Caliendo & Parro (2019)
- Empirical research using bilateral country attitudes and UN voting
  - Scott (1955), Cohen (1960), Signorio & Ritter (1999), Kuziemko & Werker (2006), Bao, Liu, Qiu & Zhu (2019), Häge (2011), Guiso, Sapienza & Zingales (2009)

Outline

- Armington
- Extensions
- Data
- Empirical Results
- Conclusions

General Armington

- Goods differentiated by country of origin with homothetic preferences

$$u_n = \frac{w_n}{\mathcal{P}\left(\mathbf{p}_n\right)}, \qquad p_{ni} \equiv \frac{\tau_{ni} w_i}{z_i}$$

- Market clearing (n is importer, i is exporter):

$$w_i \ell_i = \sum_{n=1}^{N} s_{ni} w_n \ell_n, \qquad s_{ni} = \frac{e_{ni}(\mathbf{p}_n)}{\sum_{\ell=1}^{N} e_{n\ell}(\mathbf{p}_n)}$$

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- Totally differentiate for prod. shocks, holding trade costs and endowments const.

$$\mathrm{d}\ln w_i = \sum_{n=1}^{N} t_{in} \left(\mathrm{d}\ln w_n + \left[\sum_{h=1}^{N} \left[\theta_{nih} - \sum_{k=1}^{N} s_{nk} \theta_{nkh} \right] \left[\mathrm{d}\ln w_h - \mathrm{d}\ln z_h \right] \right] \right)$$

$$\underbrace{t_{in} \equiv \frac{s_{ni} w_n L_n}{w_i L_i}}_{\substack{\text{share of } i\text{'s income} \\ \text{derived from market } n}}, \qquad \underbrace{\theta_{nih} \equiv \left(\frac{\partial \ln e_{ni}\left(\mathbf{p}_n\right)}{\partial \ln p_{nh}} \right)}_{\substack{\text{cross price elasticity of} \\ n\text{'s expenditure on } i}}$$

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$$\mathrm{d}\ln u_n = \mathrm{d}\ln w_n - \sum_{i=1}^{N} s_{ni} \left[\mathrm{d}\ln w_i - \mathrm{d}\ln z_i \right]$$

Constant Trade Elasticity

$$\text{(Income exposure)} \quad \mathrm{d}\ln w_i = \sum_{n=1}^{N} t_{in} \left(\mathrm{d}\ln w_n + \theta \left(\sum_{h=1}^{N} (s_{nh} - 1_{i=h}) \left[\mathrm{d}\ln w_h - \mathrm{d}\ln z_h \right] \right) \right)$$

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- Stacking these derivatives, we obtain "friends" and "enemies" representation

$$\underbrace{\mathrm{d}\ln \mathbf{w}}_{\text{income effect}} = \underbrace{\mathbf{T}\,\mathrm{d}\ln \mathbf{w}}_{\text{market-size effect}} + \underbrace{\theta \mathbf{M} \times \left(\mathrm{d}\ln \mathbf{w} - \mathrm{d}\ln \mathbf{z} \right)}_{\text{cross-substitution effect}}$$

$$\underbrace{\mathrm{d}\ln \mathbf{u}}_{\text{welfare effect}} = \underbrace{\mathrm{d}\ln \mathbf{w}}_{\text{income effect}} - \underbrace{\mathbf{S} \left(\mathrm{d}\ln \mathbf{w} - \mathrm{d}\ln \mathbf{z} \right)}_{\text{cost of living effect}}$$

$$\mathbf{S}_{ni} = s_{ni}, \qquad \mathbf{T}_{in} = t_{in} \equiv \frac{s_{ni} w_n L_n}{w_i L_i}, \qquad \mathbf{M}_{in} = [\mathbf{TS} - \mathbf{I}]_{in} = \sum_{h=1}^{N} t_{ih} s_{hi} - 1_{n=i}$$

Friends and Enemies

- Income exposure again:

$$\mathrm{d}\ln \mathbf{w} = \mathbf{T}\,\mathrm{d}\ln \mathbf{w} + \theta \mathbf{M} \times \left(\mathrm{d}\ln \mathbf{w} - \mathrm{d}\ln \mathbf{z}\right)$$

- Re-arranging and using world GDP as numeraire ($\mathbf{Q}\,\mathrm{d}\ln \mathbf{w} = 0$)

$$\left(\mathbf{I} - \mathbf{V}\right)\mathrm{d}\ln \mathbf{w} = -\frac{\theta}{\theta+1}\mathbf{M}\,\mathrm{d}\ln \mathbf{z}, \qquad \mathbf{V} \equiv \frac{\mathbf{T} + \theta \mathbf{T}\mathbf{S}}{\theta} - \mathbf{Q}$$

- Invert and obtain the "friends" and "enemies" income exposure matrix

$$\mathrm{d}\ln \mathbf{w} = \mathbf{W}\,\mathrm{d}\ln \mathbf{z}, \qquad \mathbf{W} = -\frac{\theta}{\theta+1}\left(\mathbf{I} - \mathbf{V}\right)^{-1}\mathbf{M}$$

- "Friends" and "enemies" welfare exposure:

$$\mathrm{d}\ln \mathbf{u} = \mathbf{U}\,\mathrm{d}\ln \mathbf{z}, \qquad \mathbf{U} \equiv \left(\mathbf{I} - \mathbf{S}\right)\mathbf{W} + \mathbf{S}$$

- Partial and general equilibrium effects

$$\mathbf{W} = -\frac{\theta}{\theta+1}\sum_{k=0}^{\infty}\mathbf{V}^k\mathbf{M} = -\underbrace{\frac{\theta}{\theta+1}\mathbf{M}}_{\text{partial equilibrium}} \underbrace{-\frac{\theta}{\theta+1}\left(\mathbf{V} + \mathbf{V}^2 + \cdots\right)\mathbf{M}}_{\text{general equilibrium}}$$

Outline

- General Armington
- Constant Elasticity Armington
- Extensions
  - Trade Imbalance ▸ more
  - Productivity and trade cost changes ▸ more
  - Small departures from constant trade elasticity ▸ more
  - Multiple industries (CDK)
  - Multiple industries and input-output linkages (CP) ▸ more
  - Economic geography (Helpman) ▸ more
- Data
- Empirical Results
- Conclusions

Multiple Industries (Costinot-Donaldson-Komunjier)

$$\underbrace{d\ln \mathbf{w}}_{\text{income effect}} = \underbrace{\mathbf{T}\, d\ln \mathbf{w}}_{\text{market-size effect}} + \underbrace{\theta \mathbf{M} \times (d\ln \mathbf{w} - d\ln \mathbf{z})}_{\text{cross-substitution effect}}$$

$$\underbrace{d\ln \mathbf{u}}_{\text{welfare effect}} = \underbrace{d\ln \mathbf{w}}_{\text{income effect}} - \underbrace{\mathbf{S}\,(d\ln \mathbf{w} - d\ln \mathbf{z})}_{\text{price index effect}}$$

$$\mathbf{T}_{in} = \sum_{k=1}^{K} t_{in}^{k} = \sum_{k=1}^{K} \frac{\alpha_n^k s_{ni}^k w_n L_n}{w_i L_i},$$

$$\mathbf{M}_{in} = \sum_{h=1}^{N} \sum_{k=1}^{K} t_{ih}^{k} s_{hi}^{k} - 1_{n=i}, \qquad \mathbf{S}_{ni} = \sum_{k=1}^{K} \alpha_n^k s_{ni}^k$$

Outline

- Theoretical framework
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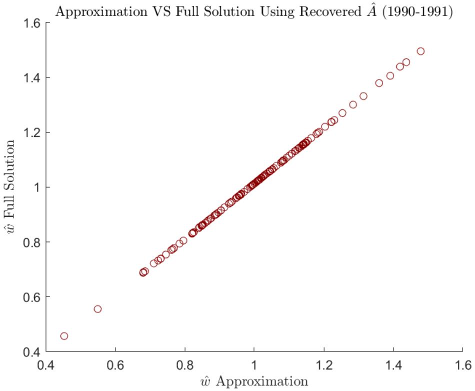
Data

- International trade data
  - United Nations COMTRADE data
  - NBER World Trade Database 1970-2012
- Income, population and distance data
  - CEPII Gravity Database 1970-2017

Outline

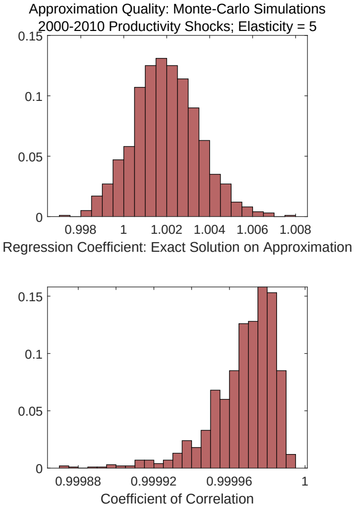
- Theoretical framework
- Data
- Empirical Results
  - Quality of the approximation
  - Impact of Chinese productivity growth
    - Effects on US welfare and income
    - Isolating the mechanisms underlying these effects
    - Effects on commodity exporting countries
    - Effects on the Asian Tigers
  - Economic and political friends and enemies
- Conclusions

Quality of the Approximation



- Use exact-hat algebra to recover (up to normalization) changes in trade costs ($\hat{\tau}_{ni}^{-\theta}$) and productivity ($\hat{z}_n$) that exactly rationalize observed trade data
- Undertake exact-hat algebra counterfactual for a change in productivity ($\hat{z}_n$)
- Compare the exact-hat algebra counterfactuals for income ($\hat{w}_n$) to the predictions of our linearization ($\frac{\mathrm{d} \ln w_n}{\mathrm{d} \ln z_n} \hat{z}_n$)

Monte Carlo Simulation



- 1,000 simulations from empirical distribution productivity shocks
- Better approximation for productivity shocks than trade cost shocks

Comparison with Exact-Hat Algebra

- Exact hat algebra by Dekle, Eaton and Kortum (2007):

$$\ln \hat{w}_i = \left(\frac{\theta}{\theta+1}\right) \ln \hat{z}_i + \frac{1}{\theta+1} \ln \left[\sum_{n=1}^{N} t_{in} \frac{\hat{w}_n}{\sum_{\ell=1}^{N} s_{n\ell} \hat{w}_\ell^{-\theta} \hat{z}_\ell^{\theta}} \right]$$

- Our bilateral friend-enemy representation can be re-written as:

$$\begin{aligned} \ln \hat{w}_i \quad \simeq \quad & \left(\frac{\theta}{\theta+1}\right) \ln \hat{z}_i + \frac{1}{\theta+1} \sum_{n=1}^{N} t_{in} \left[\begin{array}{c} \ln\left(\hat{w}_n\right) \\ +\theta \sum_{\ell=1}^{N} s_{n\ell} \left[\ln\left(\hat{w}_\ell\right) + \ln\left(\hat{z}_\ell\right)\right] \end{array} \right] \\ & + \ln \hat{\mathbf{z}}^T \mathbf{H}_{f_i} \ln \hat{\mathbf{z}} + O\left(\| \ln \hat{\mathbf{z}} \|^3\right) \end{aligned}$$

- These expressions coincide under autarky or free trade ($t_{in} = \bar{t}_n$, $s_{ni} = \bar{s}_i$)
- Quality of the approximation depends on properties of the Hessian matrix $\mathbf{H}_{f_i}$ more
- In practice, approximation almost exact, even for productivity shocks orders of magnitude larger than those implied by trade data more

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- Empirical Results
  - Quality of the approximation
  - Global productivity shocks, income and welfare
  - Economic and political friends and enemies
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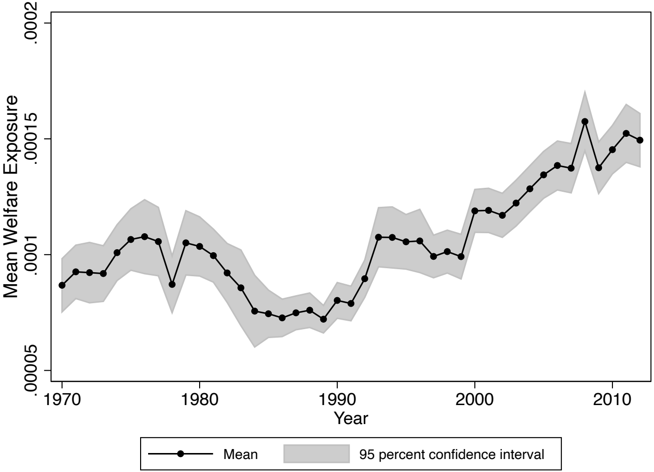
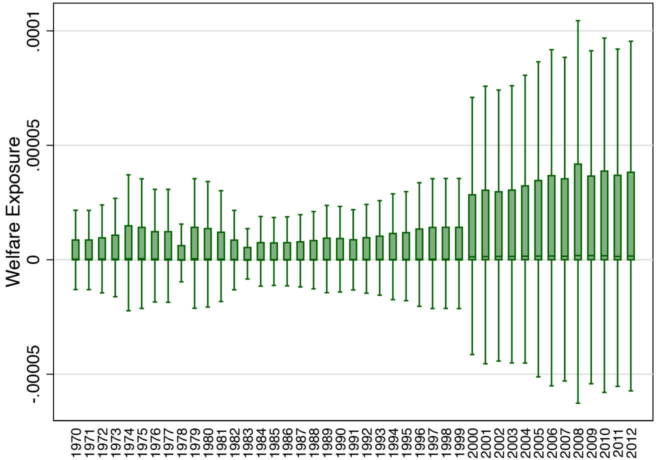
Global Welfare Exposure



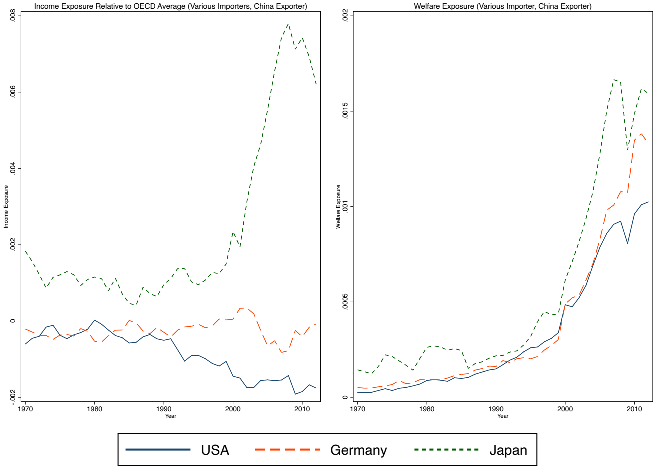
- Growing average economic interdependence, consistent with increasing globalization

Global Welfare Exposure



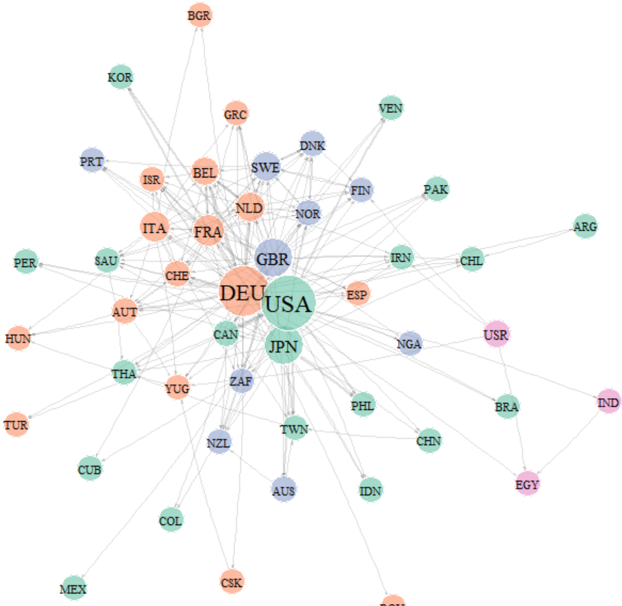
- Growing dispersion in economic interdependence, consistent with increasing globalization

Chinese Productivity Growth on U.S., Germany, and Japan

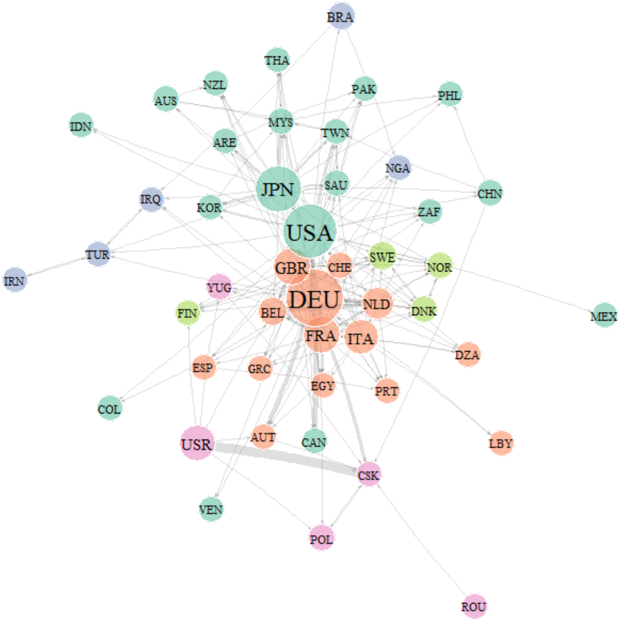


- Chinese productivity growth has reduced aggregate US relative income, but increased aggregate US welfare

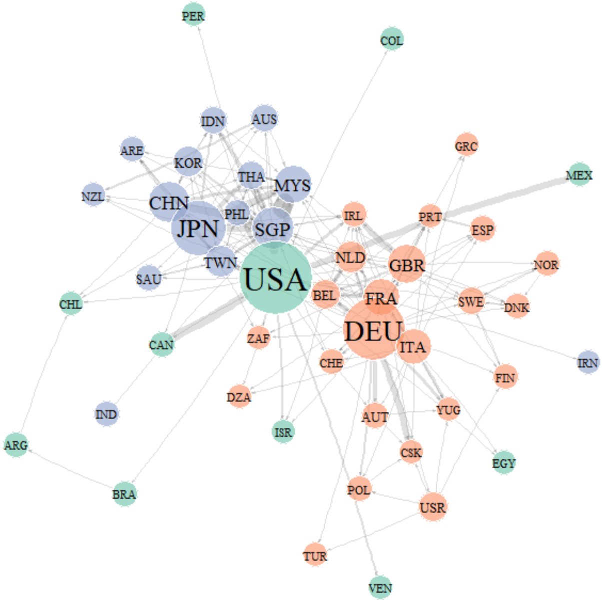
Global Welfare Exposure Network in 1970



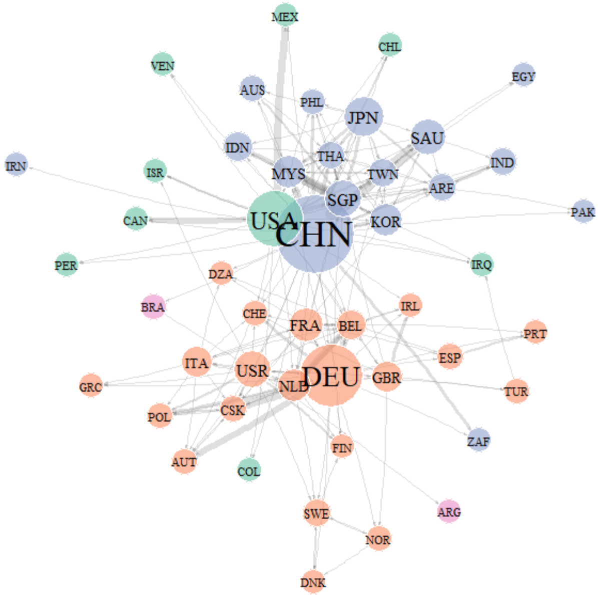
Global Welfare Exposure Network in 1985



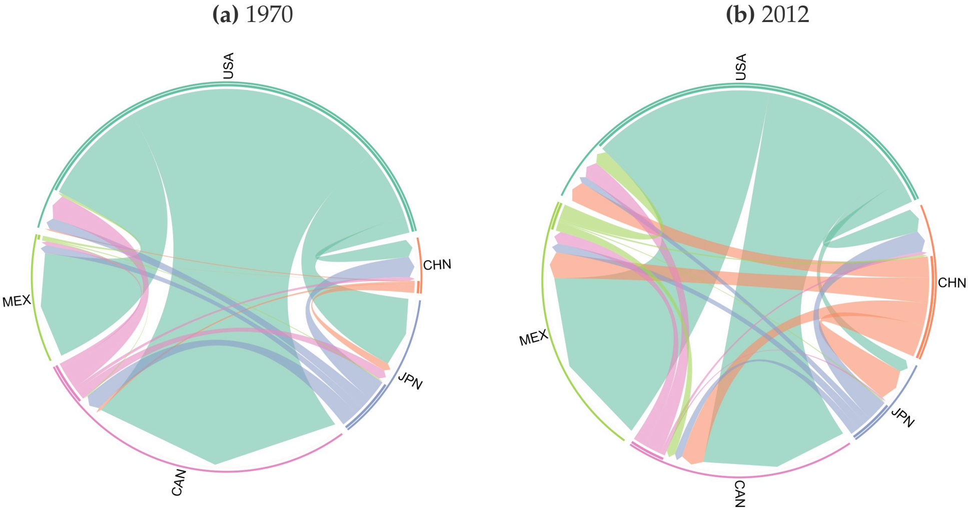
Global Welfare Exposure Network in 2000



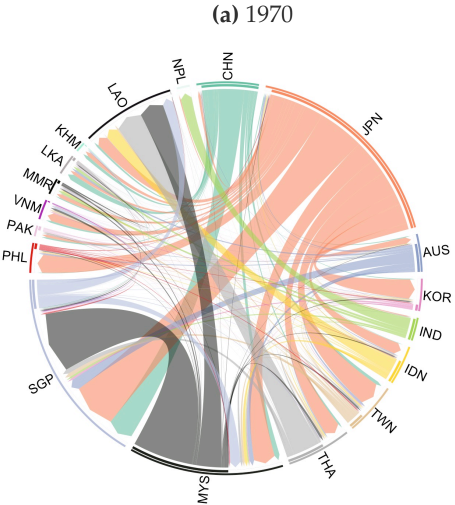
Global Welfare Exposure Network in 2012

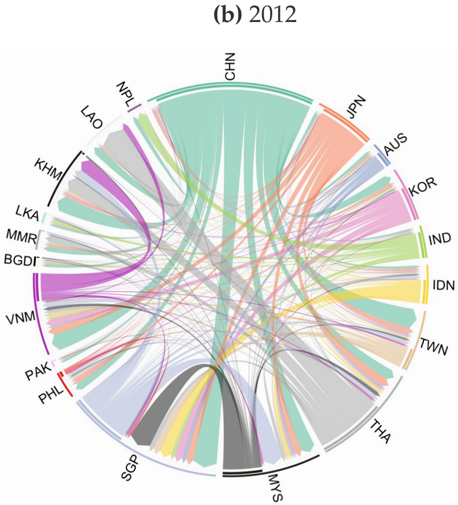


Welfare Exposure N. America



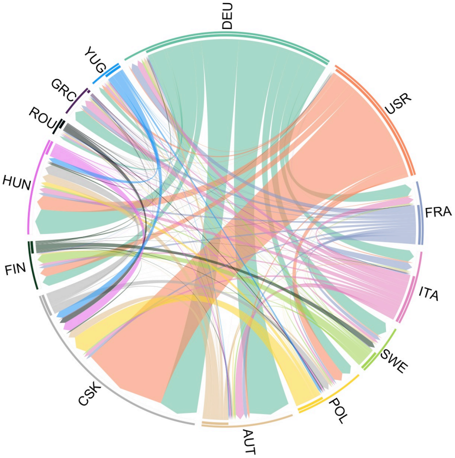
- Growing US-Mexico, Mexico-China and Mexico-US exposure



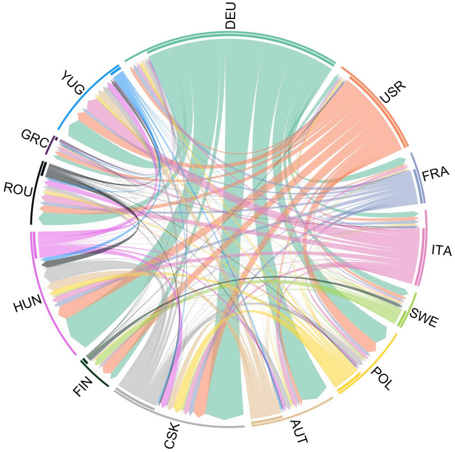


- China replaces Japan at the center of Asian trade

Welfare Exposure Europe



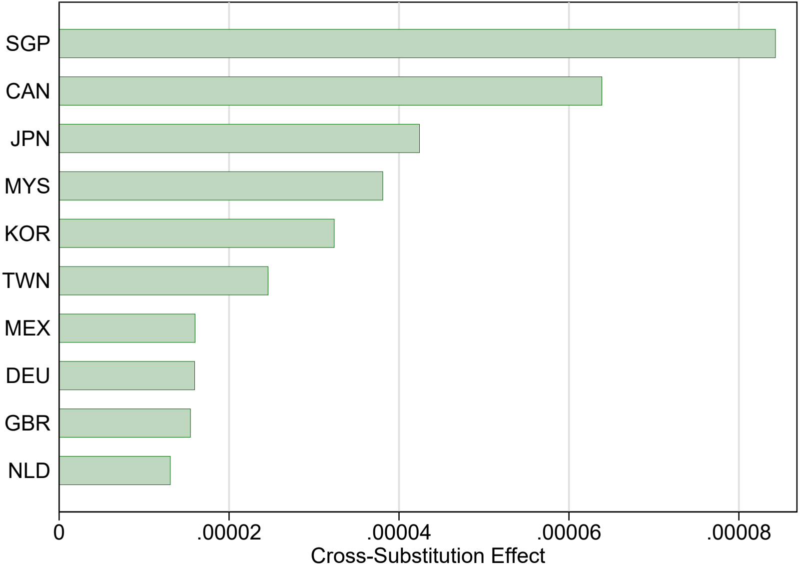
(a) 1988



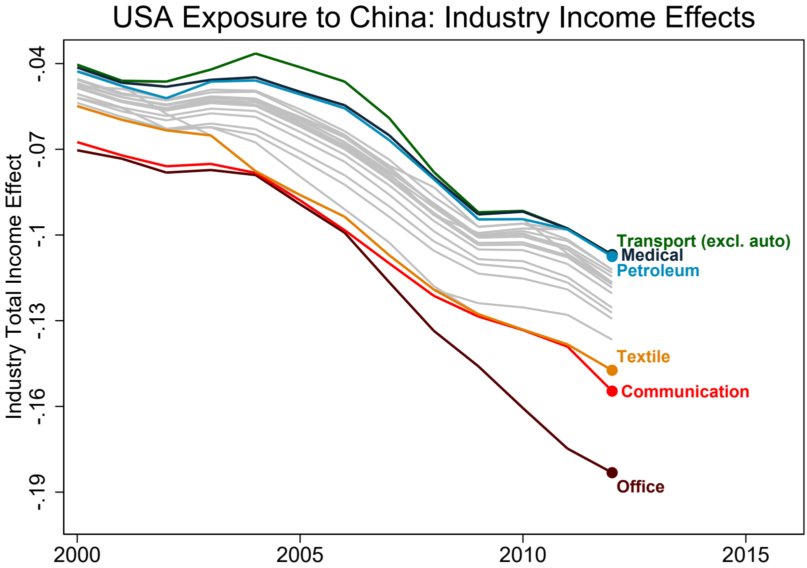
(b) 2012

- Reorientation Central European trade after the Fall of Iron Curtain

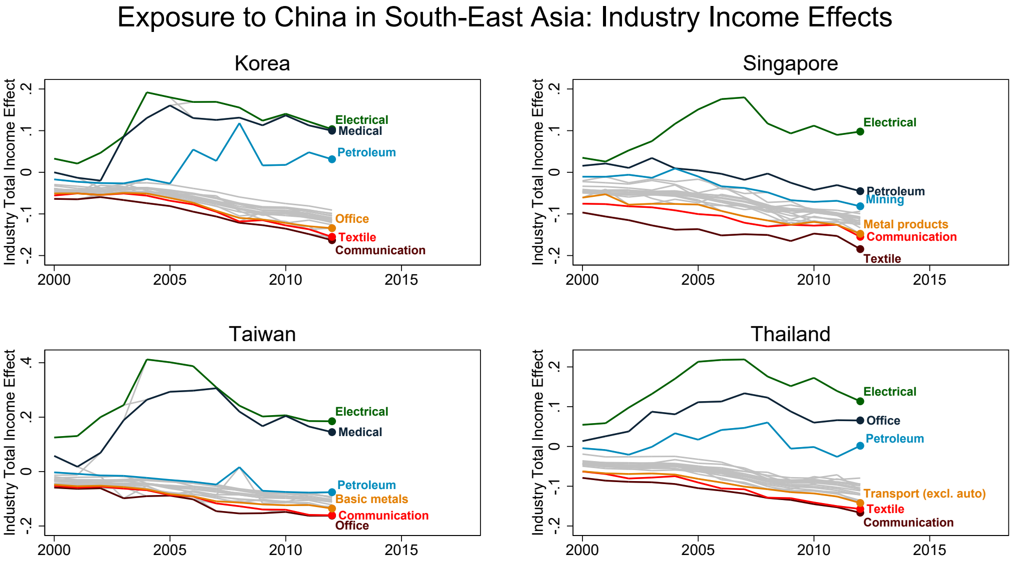
Third Market Effects of U.S. Welfare Exposure to China



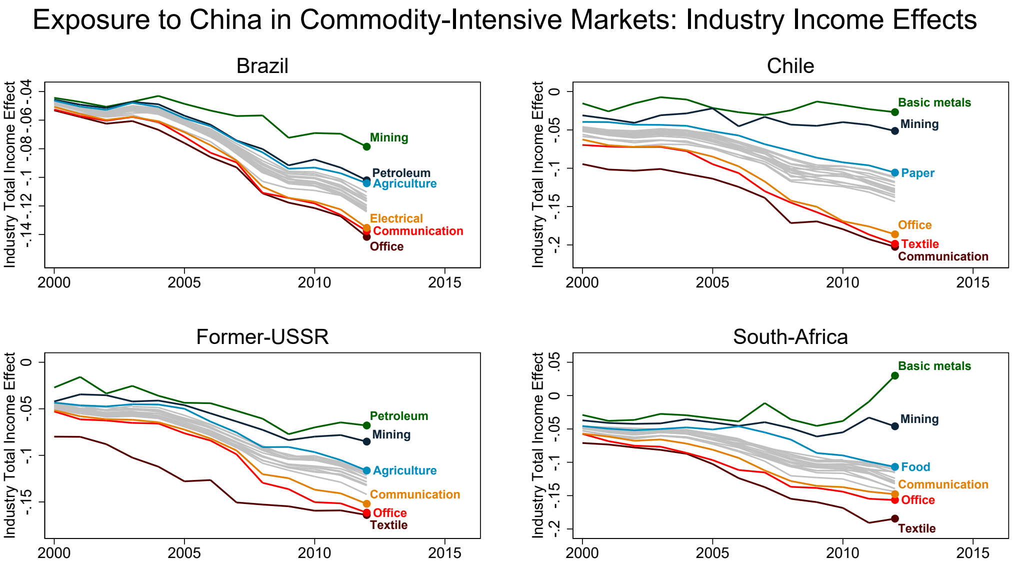
Industry-Level Income Exposure of U.S. to China



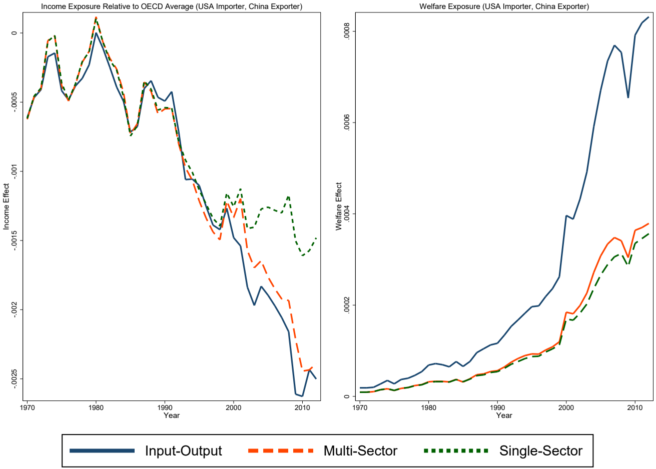
Industry-Level Income Exposure of Asian Economies to China



Industry-Level Income Exposure of Commodity Exporters to China

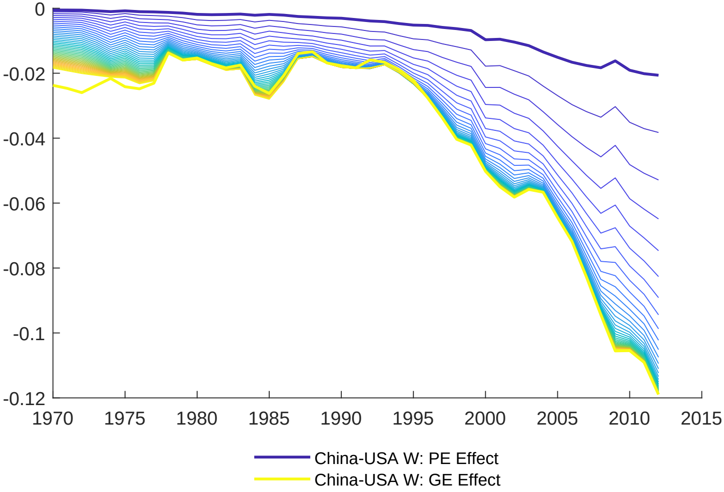


Comparisons Across Models



- Strong correlation between aggregate predictions of all three models

Partial and General Equilibrium Income Effects



Summary of Other Empirical Results

- Strong general equilibrium effects, such that inferring welfare exposure from partial equilibrium terms can be misleading ▸ more
- Both market-size and cross-substitution effects are substantial relative to overall income exposure ▸ more
- Cost-of-living effect large relative to income exposure, such that income exposure can be poor guide to welfare exposure ▸ more
- Economically relevant importer, exporter & third-market effects ▸ more
- Strong correlation between aggregate welfare predictions of single-sector, multi-sector and input-output models ▸ more
- Multi-sector and input-output models have additional disaggregated predictions for sector income exposure ▸ more
- *Chinese productivity growth strongest negative income effects for the Textiles sector and strongest positive income effects for Medical, Electrical and Petroleum sectors in other Asian countries* ▸ more

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Bilateral Political Attitudes

- Political economy debate about whether increased economic conflict between countries involves heightened political tension
  - Parallels between China-US tensions and Germany-UK around turn 20th Century and Athens-Sparta in Ancient Greece (Thucydides Trap)?
  - Reasons for skepticism: trade is not zero sum
  - Remains possible that economic exposure is predictive of political relationship

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- Consider two main measures of countries bilateral political attitudes
  - Bilateral voting similarity in United Nations General Assembly (UNGA)
  - Bilateral strategic rivalries (Thompson 2001, Colaresi et al. 2010) based on contemporary perceptions by political decision makers of competitors, threats or enemies

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- Examine whether as countries become greater economic friends, they also become greater political friends

$$A_{nit} = \beta \boldsymbol{U}_{nit} + \eta_{ni} + d_t + \epsilon_{nit}$$

  - Diff-in-diff interpretation, across time and country-pairs
  - Instrument welfare exposure $\boldsymbol{U}$ with predicted trade flows from gravity; variation arises from changes in loading on distance

Positive welfare exposure predicts bilateral voting similarity in UNGA (2SLS)

Political Outcome	Voting Similarity-S			Voting Similarity-κ			Voting Similarity-π			Distance in ideal points		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Welfare exposure in single-sector model												
$\mathbf{U}^{Single-sector}$	9.736***	9.818***	11.78***	23.09***	19.50***	21.54***	26.09***	20.10***	24.79***	-37.26***	-28.59***	-32.97***
	(2.738)	(2.307)	(2.446)	(4.644)	(4.401)	(4.434)	(5.403)	(4.647)	(4.967)	(10.82)	(9.790)	(8.535)
Panel B: Welfare exposure in multi-sector model												
$\mathbf{U}^{Multi-sector}$	9.635***	9.725***	11.66***	22.85***	19.32***	21.32***	25.82***	19.91***	24.54***	-36.87***	-28.32***	-32.64***
	(2.710)	(2.293)	(2.428)	(4.610)	(4.377)	(4.407)	(5.356)	(4.618)	(4.933)	(10.73)	(9.732)	(8.487)
Panel C: Welfare exposure in input-output model												
$\mathbf{U}^{Input-Output}$	20.41***	21.94***	26.14***	48.42***	43.59***	47.80***	54.69***	44.93***	55.00***	-76.94***	-62.99***	-72.19***
	(5.211)	(4.527)	(4.638)	(7.965)	(8.452)	(8.192)	(9.379)	(8.962)	(9.156)	(20.24)	(20.00)	(16.74)
Specification: 2SLS												
Exp × Imp	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No
Exp × Year	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Imp × Year	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
No. of Obs.	585884	585884	585884	585884	585884	585884	585884	585884	585884	567790	567790	567790
No. of Clusters	14721	14721	14721	14721	14721	14721	14721	14721	14721	14479	14479	14479

Standard errors in parentheses are clustered at country-pair level
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Negative welfare exposure predicts strategic rivalry (2SLS)

	Strategic rivalry (any type)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\mathbf{U}^{Single-sector}$	-4.741***	-5.073***	-5.379***						
	(1.782)	(1.823)	(1.960)						
$\mathbf{U}^{Multi-sector}$				-4.695***	-5.029***	-5.331***			
				(1.766)	(1.810)	(1.944)			
$\mathbf{U}^{Input-Output}$							-9.831***	-11.25***	-11.83***
							(3.495)	(3.812)	(4.054)
Specification: 2SLS									
Exp $\times$ Imp	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	No	No	Yes	No	No	Yes	No	No
Exp $\times$ Year	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Imp $\times$ Year	No	No	Yes	No	No	Yes	No	No	Yes
No. of Obs.	610954	610954	610954	610954	610954	610954	610954	610954	610954
No. of Clusters	14761	14761	14761	14761	14761	14761	14761	14761	14761

Standard errors in parentheses are clustered at country-pair level
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Conclusion: International Friends and Enemies

- We develop a bilateral matrix representation of exposure to global shocks
  - Focus on foreign productivity shocks, but methodology holds for trade cost shocks
  - Holds in ACR-plus class of models with constant trade elasticity and various extensions
    - Multi-sector environments (CDK), input-output linkages (CP), and economic geography (Helpman)

- Our representation is a linearization: exact for small shocks & one constant trade elasticity
  - We theoretically characterize the quality of the approximation for large shocks
    - Show the exact hat algebra is almost log-linear for prod. shocks given observed trade data ($R^2 > 0.999$)
  - We develop a bound for departures from a constant trade elasticity

- Our approach yields sufficient statistics that isolate economic mechanisms
  - Exports/imports; input/output markets; income/cost of living effects

- Empirical application using NBER world trade data from 1970-2012
  - Impact of Chinese productivity growth on income and welfare
  - Economic "friends or enemies" are also political "friends or enemies"

Small Departures from a Constant Trade Elasticity

- With constant trade elasticity, cross-price-elasticity for country n of the expenditure share for good i with respect to the price of good h is:

$$\theta_{nih} = \begin{cases} (s_{nh} - 1)\,\theta & \text{if } i = h \\ s_{nh}\theta & \text{otherwise} \end{cases}$$

- Without loss of generality, can represent cross-price-elasticity for any homothetic demand system as:

$$\theta_{nih} = \begin{cases} (s_{nh} - 1)\,\theta + \epsilon_{nih} & \text{if } i = h \\ s_{nh}\theta + \epsilon_{nih} & \text{otherwise} \end{cases}$$

- Noting that homotheticity implies $\sum_{k=1}^{N} s_{nk} u_{nkh} = 0$, we obtain:

$$\mathrm{d}\ln \boldsymbol{w} = \boldsymbol{T}\,\mathrm{d}\ln \boldsymbol{w} + (\theta \boldsymbol{M} + \boldsymbol{\epsilon}) \times (\,\mathrm{d}\ln \boldsymbol{w} - \,\mathrm{d}\ln \boldsymbol{z})\,,$$

$$\mathrm{d}\ln \boldsymbol{u} = \,\mathrm{d}\ln \boldsymbol{w} - \boldsymbol{S}\,(\,\mathrm{d}\ln \boldsymbol{w} - \,\mathrm{d}\ln \boldsymbol{z})\,,$$

Proposition

Let $\widetilde{\mathrm{d}\ln\mathbf{w}}$ be the solution to the general Armington model in equation and let $d\ln w$ be the solution to the constant elasticity of substitution (CES) Armington model. Then

$$\lim_{\epsilon\to 0}\frac{\|\widetilde{\mathrm{d}\ln\mathbf{w}}-\mathrm{d}\ln\mathbf{w}\|}{\epsilon\cdot\|\mathrm{d}\ln\mathbf{w}\|}\leq\frac{\theta}{\theta+1}\|\left(\mathbf{I}-\mathbf{V}\right)^{-1}\|\|\mathbf{I}-\left(\mathbf{W}+\mathbf{Q}\right)^{-1}\|$$

- In our empirical application, the RHS ranges between 1.5 and 2 using the observed trade data
- Therefore, our "friends-and-enemies" exposure measure is relatively insensitive to small perturbations in the demand system away from a constant trade elasticity back

Constant Trade Elasticity

- Consider the ACR class of trade models: (i) balanced trade, (ii) profits constant share of income, (iii) constant trade elasticity
- For example: Constant elasticity Armington (1969)
- Trade shares

$$s_{ni} = \frac{p_{ni}^{1-\sigma}}{\sum_{m=1}^{N} p_{nm}^{1-\sigma}}, \qquad \rho_{ni} \equiv \frac{\tau_{ni} w_i}{z_i}$$

- Market clearing

$$w_i L_i = \sum_{n=1}^{N} s_{ni} w_n L_n$$

- Welfare

$$u_n = \frac{w_n}{\left[\sum_{m=1}^{N} p_{nm}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}$$

Multiple Industries (CDK)

- Welfare

$$u_n = \frac{w_n}{\prod_{k=1}^K \left(p_n^k\right)^{\alpha_n^k}}, \qquad p_n^k = \gamma^k \left[\sum_{m=1}^N \left(p_{nm}^k\right)^{-\theta}\right]^{-\frac{1}{\theta}},$$

- Trade shares

$$s_{ni}^k = \frac{\left(p_{ni}^k\right)^{-\theta}}{\sum_{m=1}^N \left(p_{nm}^k\right)^{-\theta}}, \qquad p_{ni}^k \equiv \frac{\tau_{ni}^k w_i}{z_i^k}.$$

- Market clearing

$$w_i L_i = \sum_{n=1}^N \sum_{k=1}^K s_{ni}^k w_n L_n.$$

- Consider common productivity shocks: $\mathrm{d}\ln z_\ell^k = \mathrm{d}\ln z_\ell$

T Matrix

- $\boldsymbol{T}$ matrix of the share of country i's value added derived from its sales to country n

▸ Back

$$\boldsymbol{T} = \underbrace{\begin{pmatrix} T_{11} & T_{12} & \cdots & T_{1N} \\ T_{21} & T_{22} & \cdots & T_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ T_{N1} & T_{22} & \dots & T_{NN} \end{pmatrix}}_{N\times N}, \qquad T_{in} \equiv \frac{s_{ni} w_n L_n}{w_i L_i}$$

M Matrix

- With CES import demand system, the magnitude of cross-substitution effect depends on θ and share of expenditure in each market n on the goods produced by country i (s_{ni}) Back

$$\boldsymbol{M} = \underbrace{\begin{pmatrix} M_{11} & M_{12} & \dots & M_{1N} \\ M_{21} & M_{22} & \dots & M_{NN} \\ \vdots & \vdots & \ddots & \vdots \\ M_{N1} & M_{N2} & \dots & M_{NN} \end{pmatrix}}_{N \times N}, \qquad M_{in} = \sum_{h=1}^{N} t_{hi} s_{hi} - 1_{n=i}$$

S Matrix

- S Matrix with elements equal to share of country n's expenditure on country i (and hence its weight in country n's cost of living) ▸ Back

$$\boldsymbol{S} = \underbrace{\begin{pmatrix} S_{11} & S_{12} & \cdots & S_{1N} \\ S_{21} & S_{22} & \cdots & S_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ S_{N1} & S_{22} & \dots & S_{NN} \end{pmatrix}}_{N \times N}, \qquad S_{ni} = s_{ni}$$

Relationship to ACR

- Recall our expression for the log change in welfare

$$\mathrm{d}\ln u_n = \mathrm{d}\ln w_n - \sum_{m=1}^{N} s_{nm}\,\mathrm{d}\ln \rho_{nm}$$

- Choose country n's wage as the numeraire such that:

$$\mathrm{d}\ln w_n = 0, \quad \mathrm{d}\ln z_n = 0, \quad \mathrm{d}\ln \tau_{nn} = 0, \quad \mathrm{d}\ln \rho_{nn} = 0$$

- Import demand system implies

$$\mathrm{d}\ln s_{nm} - \mathrm{d}\ln s_{nn} = -\theta\left(\mathrm{d}\ln \rho_{nm} - \mathrm{d}\ln \rho_{nn}\right)$$

- Therefore change in welfare becomes:

$$\mathrm{d}\ln u_n = \sum_{m=1}^{N} \frac{\lambda_{nm}\left(\mathrm{d}\ln \lambda_{nm} - \mathrm{d}\ln \lambda_{nn}\right)}{\theta}$$

- Using $\sum_{m=1}^{N} s_{nm} = 1$ and $\sum_{m=1}^{N} \mathrm{d}s_{nm} = 0$, we obtain ACR formula

$$\mathrm{d}\ln u_n = -\frac{\mathrm{d}\ln s_{nn}}{\theta}$$

back

Taylor-Series Expansion

- Let $\tilde{z}_\ell \equiv \ln \hat{z}_\ell$; let $f_i(\tilde{\mathbf{z}})$ denote the implicit function that defines $\ln \hat{w}_i$ as a function of this vector of log productivity shocks, $\{\tilde{\mathbf{z}}\}$
- Let $\epsilon_i(\tilde{\mathbf{z}})$ denote the second-order term in the Taylor-series expansion of $f_i\{\tilde{\mathbf{z}}\}$
- The properties of this second-order term depend on the Hessian H_{f_i} of the function f_i evaluated at $\tilde{z}_\ell = 0 \; \forall \; \ell$:

$$\epsilon_i(\tilde{\mathbf{z}}) = \tilde{\mathbf{z}}^T H_{f_i} \tilde{\mathbf{z}}$$

$$H_{f_i} \equiv \begin{bmatrix} \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_1^2} & \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_1 \partial \tilde{z}_2} & \cdots & \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_1 \partial \tilde{z}_N} \\ \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_2 \partial \tilde{z}_1} & \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_2^2} & \cdots & \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_2 \partial \tilde{z}_N} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_N \partial \tilde{z}_1} & \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_N \partial \tilde{z}_2} & \cdots & \frac{\partial^2 f_i(\mathbf{0})}{\partial \tilde{z}_N^2} \end{bmatrix}$$

back

Second-Order Terms

- Let $\theta \equiv \sigma - 1$. Write the second-order Taylor expansion of $\ln \hat{w}_i \equiv f_i(\tilde{z})$ as:

$$\ln \hat{w}_i = -\theta\left(\ln \hat{w}_i - \tilde{z}_i\right) + \mathbb{E}_{T_i}\left[\ln \hat{w}_n\right] + \theta \mathbb{E}_{M_i}\left[\ln \hat{w}_n - \tilde{z}_n\right] + \epsilon_i(\tilde{z}) + O\left(\|\tilde{z}\|^3\right)$$

- where $\epsilon_i(\tilde{z}) = \tilde{z}^T H_{f_i} \tilde{z}$ represents the second-order term, and H_{f_i} is the Hessian of the implicit function $\ln \hat{w}_i \equiv f_i(\tilde{z})$, evaluated at $\tilde{z} \equiv \mathbf{0}$.
- The Hessian matrix can be explicitly written as

$$H_{f_i} = (I - T)^T V^T \left(diag\left(M_i\right) - S' diag\left(T_i\right) S\right) V (I - T) - B^T \left(diag\left(T_i\right) - T_i' T_i\right) B,$$

- where $B \equiv V(TS - I) - SV(I - T)$, recall that $V \equiv T + (\sigma - 1) M - C$, and T_i, M_i are the i-th rows of the T and M matrices, respectively.
- The second-order term $\epsilon_i(\tilde{z})$ can be re-written more intuitively as

$$\epsilon_i(\tilde{z}) = -\frac{\theta^2 \mathbb{E}_{T_i} V_{S_n}\left[\ln \hat{w}_k - \tilde{z}_k\right]}{2} + \frac{\mathbb{V}_{T_i}\left(\ln \hat{w}_i + \theta \mathbb{E}_{S_n}\left[\ln \hat{w}_k - \tilde{z}_k\right]\right)}{2},$$

where $\mathbb{E}_{T_i}$, $\mathbb{E}_{M_i}$, $\mathbb{E}_{S_n}$, V_{T_i}, and V_{S_n} are expectations and variances taken using $\{T_{in}\}_{n=1}^N$, $\{M_{in}\}_{n=1}^N$, and $\{S_{nk}\}_{k=1}^N$ as measures (e.g. $\mathbb{E}_{T_i}[X_n] \equiv \sum_{n=1}^N T_{in} X_n$, $V_{T_i}[X_n] \equiv \sum_{n=1}^N T_{in} X_n^2 - \left(\sum_{n=1}^N T_{in} X_n\right)^2$).

back

Second-Order Terms

- Weighted average of second-order terms is zero:

Proposition
Weighted by each country's income, the second order terms average to zero for any productivity shock vector: $w'\epsilon(\tilde{z}) = 0$ *for all* $\tilde{z}$.

- Bound second-order terms for an individual country:

Proposition
$|\epsilon_i(\tilde{z})| \leq |\mu^{\max,i}| \cdot \tilde{z}^T \tilde{z}$, *where* $\mu^{\max,i}$ *is the largest eigenvalue of* H_{f_i} *by absolute value. Let* $\tilde{z}^{\max,i}$ *denote the corresponding eigenvector (such that* $H_{f_i}\tilde{z}^{\max,i} = \mu^{\max,i}\tilde{z}^{\max,i}$*). The upper-bound for* $|\epsilon_i(\tilde{z})|$ *is achieved when productivity shocks are represented by* $\tilde{z}^{\max,i} : \left|\epsilon_i\left(\tilde{z}^{\max,i}\right)\right| = |\mu^{\max,i}| \cdot \left(\tilde{z}^{\max,i}\right)^T \tilde{z}^{\max,i}$

back

Second-Order Terms

- Now aggregate these results for the second-order terms for each country, and provide an upper bound on their sums of squares back

Proposition

Let $\mathcal{A} : \mathbb{R}^N \to \mathbb{R}_{\geq 0}$ denote the order-4 symmetric tensor defined by the polynomial

$$g(\tilde{z}) = \sum_{a,b,c,d=1}^{N} \left(\frac{1}{N} \sum_{i=1}^{N} \left[H_{f_i}\right]_{ab}^{2} \times \mathbf{1}_{a=c,b=d} \right) \tilde{z}_a \tilde{z}_b \tilde{z}_c \tilde{z}_d$$

where $\left[H_{f_i}\right]_{ab}$ is the ab-th entry of H_{f_i}. By construction, $g(\tilde{z}) = \langle \mathcal{A}, \tilde{z} \otimes \tilde{z} \otimes \tilde{z} \otimes \tilde{z} \rangle$ represents the inner product and is equal to the cross-equation sum-of-square of the second-order terms ($g(\tilde{z}) = \frac{1}{N} \sum_i \epsilon_i^2(\tilde{z})$) under productivity shock $\tilde{z}$. Let $\mu^{\mathcal{A}}$ be the spectral norm of $\mathcal{A}$:

$$\mu^{\mathcal{A}} \equiv \sup_{z} \frac{\langle \mathcal{A}, z \otimes z \otimes z \otimes z \rangle}{\|z\|_2^4}$$

where $\|\cdot\|_2$ is the ℓ_2 norm ($\|z\|_2 \equiv \sqrt{z^T z}$). Then

$$\sqrt{\frac{1}{N} \sum_i \epsilon_i^2(\tilde{z})} \leq \sqrt{\mu^{\mathcal{A}}} \|\tilde{z}\|_2^2 = \sqrt{\mu^{\mathcal{A}}} \tilde{z}^T \tilde{z}$$

Small Departures from a Constant Trade Elasticity

- With constant trade elasticity, cross-elasticity for country n of the expenditure share for good i with respect to the price of good h is:

$$\theta_{nih} = \begin{cases} (s_{nh} - 1)\,\theta & \text{if } i = h \\ s_{nh}\theta & \text{otherwise} \end{cases}$$

- Without loss of generality, can represent cross-elasticity for any homothetic demand system as:

$$\theta_{nih} = \begin{cases} (s_{nh} - 1)\,\theta + \epsilon_{nih} & \text{if } i = h \\ s_{nh}\theta + \epsilon_{nih} & \text{otherwise} \end{cases}$$

- Noting that homotheticity implies $\sum_{k=1}^{N} s_{nk} u_{nkh} = 0$, we obtain: back

$$\mathrm{d}\ln \boldsymbol{w} = \boldsymbol{T}\,\mathrm{d}\ln \boldsymbol{w} + (\theta \boldsymbol{M} + \boldsymbol{\epsilon}) \times (\,\mathrm{d}\ln \boldsymbol{w} - \,\mathrm{d}\ln \boldsymbol{z})\,,$$

$$\mathrm{d}\ln \boldsymbol{u} = \,\mathrm{d}\ln \boldsymbol{w} - \boldsymbol{S}\,(\,\mathrm{d}\ln \boldsymbol{w} - \,\mathrm{d}\ln \boldsymbol{z})\,,$$

Small Departures from a Constant Trade Elasticity

Proposition
Let $\widetilde{d \ln w}$ be the solution to the general Armington model in equation and let $d \ln w$ be the solution to the constant elasticity of substitution (CES) Armington model. Then

$$\frac{\|\widetilde{d \ln w} - d \ln w\|}{\|d \ln w\|} \leq \epsilon \| (I - V)^{-1} \|$$

- In our empirical application, $\| (I - V)^{-1} \|$ ranges between 1.5 and 2 using the observed trade data
- Therefore, our "friends-and-enemies" exposure measure is relatively insensitive to small perturbations in the demand system away from a constant trade elasticity back

Small Departures from a Constant Trade Elasticity

Proof.
Note the following results:

$$d \ln w = -\left(I - V\right)^{-1} \theta M d \ln z$$

$$\widetilde{d \ln w} = -\left(I - V + u\right)^{-1} \theta M d \ln z$$

From perturbation theory, we know $\frac{\|\widetilde{d \ln w} - d \ln w\|}{\|d \ln w\|} \leq K\left(I - V\right) \frac{\|u\|}{\|I - V\|}$, where $K\left(A\right) \equiv \|A\| \|A^{-1}\|$ is the condition number of matrix A. Note $\|u\| = \epsilon$ and the proposition follows. ▸ back □

Trade Imbalance

- Instantaneous welfare is the real value of expenditure (X_n)

$$u_n = \frac{X_n}{p_n} = \frac{w_n L_n + d_n}{p_n}$$

- Market clearing requires that income equals expenditure

$$w_i L_i = \sum_{n=1}^{N} s_{ni} \left[w_n L_n + d_n \right]$$

- Comparative statics for income and welfare ▸ back

$$d \ln w_i = \sum_{n=1}^{N} t_{ni} \left(\Omega_n^{-1} d \ln w_n + \theta \left(\sum_{h=1}^{N} s_{nh} d \ln p_{nh} - d \ln p_{ni} \right) \right) + \sum_{n=1}^{N} t_{ni} \left(\Omega_n - 1 \right) d \ln d_n$$

$$d \ln u_n = \Omega_n^{-1} d \ln w_n + \left(1 - \Omega_n^{-1} \right) d \ln d_n - \sum_{m=1}^{N} s_{nm} d \ln p_{nm}$$

$$\Omega_n \equiv \frac{w_n L_n + d_n}{w_n L_n}$$

Productivity and Trade Cost Shocks

- Income and welfare effects

$$\mathrm{d}\ln w_i = \sum_{n=1}^{N} t_{ni} \left(\mathrm{d}\ln w_n + \theta \left(\sum_{h=1}^{N} s_{nh} \left[\begin{array}{c} \mathrm{d}\ln w_h + \mathrm{d}\ln \tau_{nh} \\ - \mathrm{d}\ln z_h \end{array} \right] - \left[\begin{array}{c} \mathrm{d}\ln w_i + \mathrm{d}\ln \tau_{ni} \\ - \mathrm{d}\ln z_i \end{array} \right] \right) \right)$$

$$\mathrm{d}\ln u_n = \mathrm{d}\ln w_n - \sum_{i=1}^{N} s_{ni} \left[\mathrm{d}\ln w_i + \mathrm{d}\ln \tau_{ni} - \mathrm{d}\ln z_i \right]$$

- Stacking these derivatives for all countries i (rows) and h (columns), obtain "friends" and "enemies" representation back

$$\mathrm{d}\ln \boldsymbol{w} = \boldsymbol{T}\,\mathrm{d}\ln \boldsymbol{w} + \theta \boldsymbol{M} \left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z} \right) + \theta \left(\boldsymbol{T}\,\mathrm{d}\ln \boldsymbol{\beta} - \mathrm{d}\ln \boldsymbol{\gamma} \right)$$

$$\mathrm{d}\ln \boldsymbol{u} = \mathrm{d}\ln \boldsymbol{w} - \boldsymbol{S} \left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z} \right) - \mathrm{d}\ln \boldsymbol{\beta}$$

- where

$$\mathrm{d}\ln \beta_n \equiv \sum_{h=1}^{N} s_{nh}\, \mathrm{d}\ln \tau_{nh}, \qquad \mathrm{d}\ln \gamma_i \equiv \sum_{n=1}^{N} T_{in}\, \mathrm{d}\ln \tau_{ni}$$

Multi-Industry IO (CP)

- Impact of a productivity shock in h on wages and welfare in i
- Stacking these impacts for all countries i (rows) and h (columns)

$$\underbrace{\mathrm{d}\ln \boldsymbol{w}}_{\text{income effect}} = \underbrace{\mathbf{T}\,\mathrm{d}\ln \boldsymbol{w}}_{\text{market size effect}} + \underbrace{\theta\mathbf{M}}_{\text{substitution effect}} \times \underbrace{\left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z}\right)}_{\text{change in costs}}$$

$$\underbrace{\mathrm{d}\ln \boldsymbol{u}}_{\text{welfare effect}} = \underbrace{\mathrm{d}\ln \boldsymbol{w}}_{\text{income effect}} - \underbrace{\mathbf{S}\left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z}\right)}_{\text{change in price indices}}$$

back

Economic Geography

- Economy consists of set of locations indexed by $i, n \in \{1, \ldots, N\}$
- Economy as a whole has an exogenous supply of $\bar{L}$ workers
- Workers are perfectly mobile with idiosyncratic preferences

$$u_n(\nu) = \frac{B_n b_n(\nu) w_n}{p_n}$$

- Armington consumption goods price index

$$p_n = \left[\sum_{i=1}^{N} p_{ni}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \qquad \sigma > 1$$

- Idiosyncratic preferences Fréchet distributed

$$F_b(b) = \exp\left(-b^{-\kappa}\right), \qquad \kappa > 1$$

- Linear production technology back

$$p_{ni} = \frac{\tau_{ni} w_i}{z_i}$$

Economic Geography

- Trade shares

$$s_{ni} = \frac{\left(\tau_{ni} w_i / z_i\right)^{1-\sigma}}{\sum_{m=1}^{N} \left(\tau_{nm} w_m / z_m\right)^{1-\sigma}}$$

- Population shares

$$\xi_n \equiv \frac{L_n}{\bar{L}} = \frac{\left(B_n w_n / p_n\right)^{\kappa}}{\sum_{h=1}^{N} \left(B_h w_h / p_h\right)^{\kappa}}$$

- Expected utility

$$\mathbb{E}\left[u\right] = \bar{u} = \Gamma\left(\frac{\kappa - 1}{\kappa}\right) \left[\sum_{h=1}^{N} \left(B_h w_h / p_h\right)^{\kappa}\right]^{\frac{1}{\kappa}}$$

Economic Geography

- Impact of productivity shocks on income, population and welfare has a bilateral friend-enemy matrix representation
- Wages

$$d \ln \boldsymbol{w} = \boldsymbol{T} d \ln \boldsymbol{w} + \left[\left(\frac{(\sigma - 1) - \kappa}{1 + \kappa} \right) \boldsymbol{TS} - \left(\frac{\sigma - 1}{1 + \kappa} \right) \boldsymbol{I} + \frac{\kappa}{1 + \kappa} \boldsymbol{S} \right] (d \ln \boldsymbol{w} - d \ln \boldsymbol{z})$$

- Population shares

$$d \ln \boldsymbol{\xi} = \kappa \left(I - \boldsymbol{\mathcal{L}} \right) \left[d \ln \boldsymbol{w} - \boldsymbol{S} \left(d \ln \boldsymbol{w} - \boldsymbol{I} \right) \right]$$

- Welfare

$$d \ln \bar{\boldsymbol{u}} = \xi' \left[d \ln \boldsymbol{w} - \boldsymbol{S} \left(d \ln \boldsymbol{w} - \boldsymbol{I} \right) \right]$$

- where back

$$\boldsymbol{\mathcal{L}} = \underbrace{\begin{pmatrix} \xi_1 & \xi_2 & \cdots & \xi_N \\ \xi_1 & \xi_2 & \cdots & \xi_N \\ \vdots & \vdots & \ddots & \vdots \\ \xi_1 & \xi_2 & \ldots & \xi_N \end{pmatrix}}_{N \times N}$$

DEK Validation

- Recover productivity and trade cost shocks that exactly rationalize the observed trade data
- Estimate trade costs

$$-\theta \ln d_{nit} = u^{M}_{nt} + u^{X}_{it} - \delta_t \theta \ln \text{dist}_{ni} + u^{I}_{nit}$$

$$\ln X_{nit} = \mu_{nt} + \eta_{it} + \phi_t \ln \text{dist}_{ni} + \varepsilon_{nit}$$

$$\hat{d}^{-\theta}_{nit} = \left(\frac{d_{nit}}{d_{nit-1}}\right)^{-\theta} = \text{dist}^{\hat{\phi}_t}_{ni} \exp\left(\hat{\varepsilon}_{nit}\right)$$

- Recover implied changes in productivity that exactly rationalize changes in income given changes in trade costs from market clearing backtheory backdata

$$\hat{w}_{it} w_{it} L_{it} = \sum_{n=1}^{N} \frac{s_{nit} \hat{d}^{-\theta}_{nit} \left(\hat{w}_{it} / \hat{z}_{it}\right)^{-\theta}}{\sum_{\ell=1}^{N} s_{n\ell t} \hat{d}^{-\theta}_{n\ell t} \left(\hat{w}_{\ell t} / \hat{z}_{\ell t}\right)^{-\theta}} \hat{w}_{nt} w_{nt} L_{nt}$$

DEK Validation

- Undertake DEK counterfactual for productivity growth

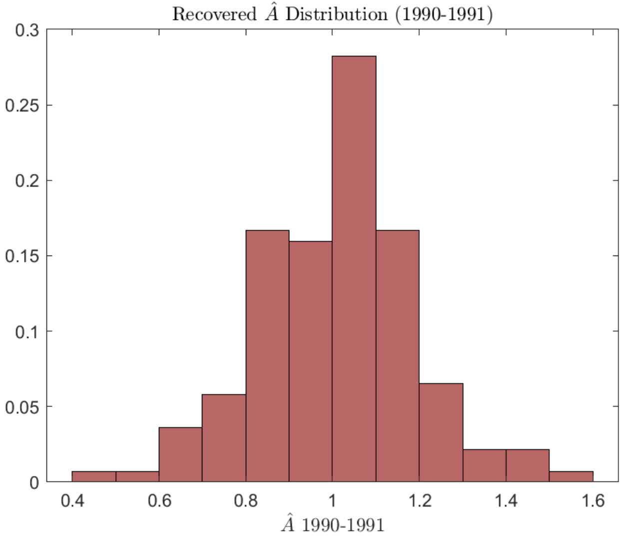
$$\hat{w}_{it} w_{it} L_{it} = \sum_{n=1}^{N} \frac{s_{nit} \hat{w}_{it}^{-\theta} \hat{z}_{it}^{\theta}}{\sum_{\ell=1}^{N} s_{n\ell t} \hat{w}_{\ell t}^{-\theta} \hat{z}_{\ell t}^{\theta}} \hat{w}_{nt} w_{nt} L_{nt}$$

- Compare DEK counterfactual to our linearization ▸ back ▸ backdata

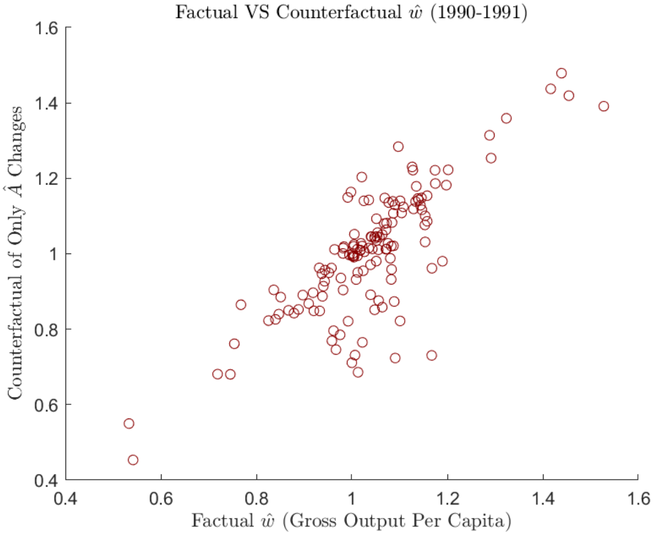
$$\ln \hat{w}_i = \left(\frac{\theta}{\theta+1} \right) \ln \hat{z}_i + \frac{1}{\theta+1} \ln \left[\sum_{n=1}^{N} t_{ni} \frac{\hat{w}_n}{\sum_{\ell=1}^{N} s_{n\ell} \hat{w}_{\ell}^{-\theta} \hat{z}_{\ell}^{\theta}} \right].$$

$$\ln \hat{w}_i = \left(\frac{\theta}{\theta+1} \right) \ln \hat{z}_i + \frac{1}{\theta+1} \sum_{n=1}^{N} t_{ni} \left[\begin{array}{c} \ln(\hat{w}_n) \\ +\theta \sum_{\ell=1}^{N} s_{n\ell} \left[\ln(\hat{w}_{\ell}) + \ln(\hat{z}_{\ell}) \right] \end{array} \right].$$

Distribution of Recovered $\hat{A}$



Actual Versus Counterfactual $\hat{w}$



Foreign Policy Similarity

- Consider two vectors of binary voting outcomes for two countries

$$X_i \in \{0,1\} \quad \text{and} \quad Y_i \in \{0,1\} \quad \text{for} \quad i \in \{1,\ldots,I\}.$$

- Consider the following S-score measure of the distance between these two vectors (Signorino and Ritter 1999)

$$S = 1 - 2 \times \frac{\sum_{i=1}^{I} (X_i - Y_i)^2}{D_{\text{max}}}$$

$$D_{\text{max}} = \sum_{i=1}^{I} d_{\text{max}} = I$$

- With binary data, the maximum possible dissimilarity for each outcome is $d_{\text{max}} = 1$
- $S \in [-1,1]$, with $S = -1$ corresponding to maximum dissimilarity, and $S = 1$ corresponding to maximum similarity back

Chance Corrected Measures

- Chance corrected measures of foreign policy similarity
  - D_o : Observed dissimilarity
  - D_e : Dissimilarity expected by chance

$$\text{Chance Corrected} = 1 - \frac{D_o}{D_e}$$

- With binary data, D_o is the sum of the off-diagonal elements of the contingency table

$$D_o = \sum_{i \neq j} p_{ij}$$

- With binary data, D_e is obtained from the product of the marginal proportions for the off-diagonal elements

$$D_e = \sum_{i \neq j} m_{i.} m_{j.}$$

Chance Corrected Measures

- Reinterpret S-score as a form of chance-corrected measure ▸ more

$$D_e = (1/2)^2 + (1/2)^2 = 1/2$$

$$S = 1 - \frac{D_o}{D_e} = 1 - \frac{\sum_{i \neq j} p_{ij}}{1/2}$$

- Scott's π adjusts for the frequency of zeros and ones but assumes homogeneous marginal distributions of zeros and ones ▸ more

$$\pi = 1 - \frac{D_o}{D_e} = 1 - \frac{\sum_{i \neq j} p_{ij}}{\sum_{i \neq j} \left(\frac{p_{i.} + p_{.i}}{2}\right)\left(\frac{p_{j.} + p_{.j}}{2}\right)}$$

- Cohen's κ adjusts for the frequency of zeros and ones using the observed marginal distributions ▸ more

$$\kappa = 1 - \frac{D_o}{D_e} = 1 - \frac{\sum_{i \neq j} p_{ij}}{\sum_{i \neq j} p_{i.} p_{.j}}$$

- Compute these measures for each exporter-importer-year observation using data on UN assembly votes within that year ▸ more

Similarity Measures (Non-Binary)

- Consider vectors X_i and Y_i that record vote outcomes $i \in \{1, \ldots, I\}$:

$$X_i \in \{1, 2, 3\} \qquad \text{and} \qquad Y_i \in \{1, 2, 3\}, \qquad i \in \{1, \ldots, I\}$$

- S-score

$$\mathbb{S}^S = 1 - \frac{\sum_{i=1}^{I} (X_i - Y_i)^2}{\frac{1}{2}\sum_{i=1}^{I} (d_{\mathsf{max}})^2}, \qquad (d_{\mathsf{max}})^2 = \mathsf{sup}\{(X_i - Y_i)\}^2$$

- π-score

$$\mathbb{S}^\pi = 1 - \frac{\sum_{i=1}^{I} (X_i - Y_i)^2}{\sum_{i=1}^{I} \left(X_i - \frac{\bar{X}+\bar{Y}}{2}\right)^2 + \sum_{i=1}^{I} \left(Y_i - \frac{\bar{X}+\bar{Y}}{2}\right)^2}$$

- κ-score back

$$\mathbb{S}^\kappa = 1 - \frac{\sum_{i=1}^{I} (X_i - Y_i)^2}{\sum_{i=1}^{I} (X_i - \bar{X})^2 + \sum_{i=1}^{I} (Y_i - \bar{Y})^2 + \sum_{i=1}^{I} (\bar{X} - \bar{Y})^2}$$

S-Score

(a) Observed Dissimilarity

	0	1	
0	.30	.20	.50
1	.20	.30	.50
	.50	.50	1

$$D_o = 0.20 + 0.20 = 0.40$$

(b) Chance Dissimilarity

	0	1	
0	.25	.25	.50
1	.25	.25	.50
	.50	.50	1

$$D_e = (0.5)^2 + (0.5)^2$$

$$D_e = 0.25 + 0.25 = 0.5$$

Scott's π

(a) Observed Dissimilarity

	0	1	
0	.30	.20	.50
1	.20	.30	.50
	.50	.50	1

$$D_o = 0.20 + 0.20 = 0.40$$

(b) Chance Dissimilarity

	0	1	
0	.25	.25	.50
1	.25	.25	.50
	.50	.50	1

$$D_e = \left(\frac{0.5+0.5}{2}\right)^2 + \left(\frac{0.5+0.5}{2}\right)^2$$

$$D_e = 0.25 + 0.25 = 0.5$$

$$\pi = 1 - \frac{0.40}{0.50} = 0.20$$

Cohen's κ

(a) Observed Dissimilarity

	0	1	
0	.30	.20	.50
1	.20	.30	.50
	.50	.50	1

$$D_o = 0.20 + 0.20 = 0.40$$

(b) Chance Dissimilarity

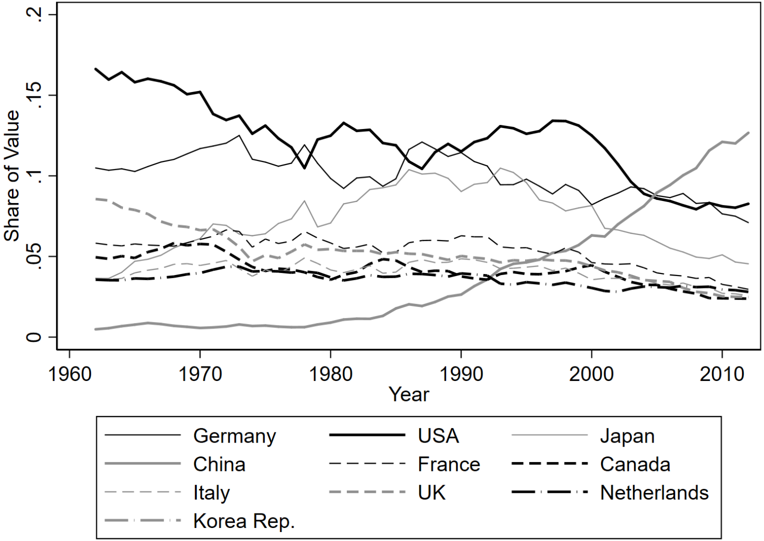
	0	1	
0	.25	.25	.50
1	.25	.25	.50
	.50	.50	1

$$D_e = (0.5)^2 + (0.5)^2$$

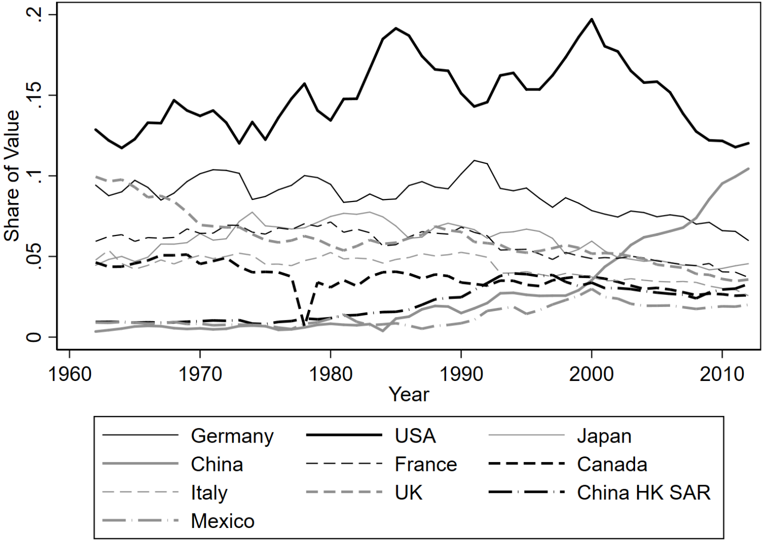
$$D_e = 0.25 + 0.25 = 0.5$$

$$\kappa = 1 - \frac{0.40}{0.50} = 0.20$$

Exporter Shares



Importer Shares



Correlation Countries Bilateral Attitudes

	$\mathbb{S}^S$	$\mathbb{S}^\kappa$	$\mathbb{S}^\pi$	$\mathbb{D}$	$\mathbb{R}$	$\mathbb{P}$
	UNGA Voting Similarity			Distance in Ideal Points	Rivalry	PEW Survey
$\mathbb{S}^S$	1					
$\mathbb{S}^\kappa$	.674	1				
$\mathbb{S}^\pi$	.870	.940	1			
$\mathbb{D}$	-.906	-.738	-.868	1		
$\mathbb{R}$	-.115	-.036	-.070	.075	1	
$\mathbb{P}$	.247	.393	.351	-.322	-.220	1

more

t-statistics Within Country-Partner Pairs

	$\mathbb{S}^{\kappa}$	$\mathbb{S}^{\pi}$	$\mathbb{D}$	$\mathbb{R}$	$\mathbb{P}$
$\mathbb{S}^{S}$	494.78	682.33	-652.17	-11.5	9.81